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Real-time large deformations: A probabilistic deep learning approach

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Many engineering applications are benefited by predicting the deformations of structures in advance, some of them even require real-time responses [1][2]. The finite Element Method (FEM) is the most widely used approach to solve these problems, although, it is computationally expensive, particularly when capturing non-linear responses characteristic to large deformation regimes.

In this work, we propose an efficient probabilistic deep learning surrogate framework that is capable of accurately and efficiently predicting non-linear deformations of bodies together with the predictions' uncertainties [3]. The framework uses a special convolutional neural network architecture (U-Net), which directly takes the Finite Element nodal forces at the neural network input to give nodal displacements at its output. The probabilistic part of the framework is based on a dedicated Variational Inference formulation, thanks to which we are not only able to efficiently capture uncertainties related to noisy data, but we have also knowledge about the model uncertainties—which is especially important in regions not well supported by the data (e.g., the extrapolated region).

Based on several benchmark implementations, we show the predictive capabilities of the framework. We could achieve the real-time constraint by gaining 350 times speedup when compared to FEM. Our framework enabled us to capture the data noises as well as the model uncertainties, thus taking a step towards making real-time large deformation simulations more trustworthy.

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